Wireline Applied Stimulation Pulsing (WASP®) Technology
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Company Overview

Blue Spark was formed in 2011

➢ Service company focus on developing ‘High Pulse Power’ for oilfield applications.
  ➢ Management & Operational Headquarters in Calgary, Canada
  ➢ Research & Development Centre in Toulouse, France
  ➢ Parent Company: I-Pulse Inc.

➢ Technology:
  ➢ Unique wireline-deployed tool for generating shock waves in the well-bore
    ➢ Production stimulation
    ➢ Scale removal

➢ Operations:
  ➢ First commercial operation in September 2011 in Canada
  ➢ First offshore, horizontal operation in June 2013 – North Sea
Demonstration of High-Pulsed Power

NOTE: The Blue Spark tool uses much, much less energy than was used in this demonstration!!!!!!
High-Pulsed Power technologies convert a low power electrical input into a very high power electrical output for an extremely brief period of time, similar to lightning.
Introduction to High-Pulsed Power
Blue Spark Tool Evolution – WASP®
(Wireline Applied Stimulation Pulsing)

<table>
<thead>
<tr>
<th>Tool Diameter</th>
<th>Minimum Restriction</th>
<th>Operating Temp (Max)</th>
<th>Operating Pressure (Max)</th>
<th>Toll Length (Max)</th>
</tr>
</thead>
<tbody>
<tr>
<td>WASP 550</td>
<td>5.5” (139.7 mm)</td>
<td>176°F (80°C)</td>
<td>5,000 psi (345 bar)</td>
<td>42.6 ft (12.98 m)</td>
</tr>
<tr>
<td></td>
<td>5.6” (142 mm)</td>
<td>24°F (−12°C)</td>
<td>5,800 psi (400 bar)</td>
<td>27.9 ft (8.5 m)</td>
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<tr>
<td>WASP 400</td>
<td>4” (101.6 mm)</td>
<td>248°F (120°C)</td>
<td>5,800 psi (400 bar)</td>
<td>38.1 ft (11.61 m)</td>
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<tr>
<td></td>
<td>4.1” (104 mm)</td>
<td>248°F (120°C)</td>
<td>5,000 psi (345 bar)</td>
<td>27.9 ft (8.5 m)</td>
</tr>
<tr>
<td>WASP 275</td>
<td>2.75” (69.9 mm)</td>
<td>266°F (130°C)</td>
<td>10,000 psi (700 bar)</td>
<td>38.1 ft (11.61 m)</td>
</tr>
<tr>
<td></td>
<td>2.85” (72 mm)</td>
<td>248°F (120°C)</td>
<td>10,000 psi (700 bar)</td>
<td>27.9 ft (8.5 m)</td>
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<tr>
<td>WASP 212P</td>
<td>2.125” (54.0 mm)</td>
<td>248°F (120°C)</td>
<td>10,000 psi (700 bar)</td>
<td>42.8 ft (13.16 m)</td>
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<tr>
<td></td>
<td>2.135” (56 mm)</td>
<td>248°F (120°C)</td>
<td>10,000 psi (700 bar)</td>
<td>27.9 ft (8.5 m)</td>
</tr>
</tbody>
</table>

WASP® can be conveyed by e-line, e-Coil or tractor into vertical or horizontal wells.
Perforation Cleanup Demonstration

5 inch “perforated” casing, wrapped with reinforced concrete

*Before*

Energy passes through entrance holes and disaggregates blockages (scale). Steel reflects and attenuates the hydraulic impulse therefore cement directly behind casing is undamaged.

*WASP treatment*

*After*
A sample Cement Bond Log run on a well immediately before and after stimulation. The bond log confirms that EHS does not negatively impact cement bond or casing integrity. The first 11 wells had bond logs run to confirm this.
Current Industry Solutions for Conventional Near-Wellbore Damage

**Mechanical**
- Milling, Brushes, Explosives (string shots)
- Ineffective in perforations & screens
- Risk of damage to completion equipment
- Limited effectiveness in complex profiles

**Chemical**
- Placement (path of least resistance)
- Unintended / undesirable chemical changes
- Corrosion
- Environmental Risk

**Re-Perforating**
- Integrity of completion (screens, poor cement)
- Transportation and handling of explosives
- Effectiveness limited by physical constraints
- Skin associated with crushed zone
Wasp Applications

➢ Formation Damage Remediation
➢ Slotted Liner/Gravel Pack Clean Up
➢ Perforated Liner & Sand Screen Clean Up
➢ Scale Removal
➢ Subsurface Equipment Clean Up (safety valve, side pocket mandrels, sliding sleeves)
➢ Injection Wells, EOR
➢ Injection Wells, Disposal Wells
➢ Chemical Treatment Enhancement
➢ TBD
  ➢ P&A, Casing patches, wellhead cleaning……
WASP® Applications: Scale Removal

➢ Upper Completion

➢ Sub Surface Safety Valves
➢ Gas Lift Valves
➢ Sliding Sleeves
➢ Wellhead Valves

➢ Lower Completion

➢ Sand Screens
➢ Gravel Packs
➢ Perforated Liner
➢ Slotted Liner
Scale Removal from Casing Sample

- Casing from Belridge Field, Cali – FeS and FeCO₃ scale
- Casing has corrosion from H₂S in injection water
- Scale broken within 10 pulses
- No visible damage to casing, including where corrosion was severe

Before

After
Surface Test - Iron Carbonate Scale

- A section of 9-5/8” casing with predominantly Iron Carbonate scale deposit provided by a client.
- After 30 pulses most of the scale was removed.
- After an additional 30 pulses (60 total) the inside of the casing was completely clean.

Attempts to remove scale with a hammer and chisel
CHALLENGE

Client well continually developed calcium carbonate scale (CaCO3) in the perforations, reducing production. Client was interested in using the WASP® tool to remove the scale from the perforations and to test scale removal from inside the casing. Determine the optimal pulsing rate for removing scale in casing, to maximize efficiency.

OUTCOME

- The post-WASP® multi-finger caliper confirmed that 100% of scale was removed at a pulsing rate of 60 pulses/ft.
- Oil production increased from 4.8 bbls/day to 8.5 bbls/day when comparing the 3-month pre-WASP® to 3-month post-WASP® rates.

SOLUTION

Remove scale and improve connectivity to the reservoir using electro-hydraulic stimulation technology.
- A pre-WASP® multi-finger caliper log was run to identify the thickness of scale in casing.
- The perforated interval of the well was stimulated with WASP®.
- A post-WASP® multi-finger caliper log was run.

POST-STIMULATION RESULTS:

100% CaCO3 scale removed
77% increased oil production

 average rates

<table>
<thead>
<tr>
<th>3 months pre-WASP®</th>
<th>3 months post-WASP®</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.8</td>
<td>8.5</td>
</tr>
</tbody>
</table>
Case Study: Scale Removal from WI Vessel

➢ Challenge:
  ➢ Operator believed subsea well had potential to be a significant producer.
  ➢ But significant scale present in well, including across HOS and SSSV.
  ➢ Well Intervention Vessel planned to achieve CT & WL intervention work scope.
  ➢ CT milling operation planned to remove scale in the well & return SSSV to operation.
  ➢ CT milling operation not achieved - programme changed to set suspension plug in tubing

➢ Solution:
  ➢ Blue Spark WASP® technology selected as preferred solution to treat HOS & SSSV after CT milling.
  ➢ WASP® equipment & Engineer mobilised offshore & deployed with operator’s preferred CT & wireline provider.
  ➢ WASP® treatment performed across section of tubing – total well intervention time – less than 12 hours.

➢ Outcome:
  ➢ Scale removed from tubing
  ➢ Suspension plug set – tested successfully
Case Study: Tubing Scale Removal: Workover Operations

➢ Challenge:

➢ Major North Sea operator required scale-free sections of tubing for plug set & tubing cut prior to pulling the completion.

➢ Objective previously achieved from jack-up rig using Coiled Tubing & jetting technology (fluids & abrasives).

➢ Solution:

➢ WASP® deployed on operator’s preferred wireline provider & performed from platform, prior to jack-up arrival on location.

➢ Two specific tubing sections treated with WASP® in a single wireline run - total WASP® treatment time less than 4 hours. Results verified by caliper log. Total of 48 hours including wireline rig up/down.

➢ Client Benefits:

➢ Reduction of 8 days in jack-up rig time - WASP® operation performed offline.

➢ Requirement for Coil Tubing eliminated – mobilisation, rig-up, rig-down, reduced crew.
➢ Caliper log results:
WASP® effective in removing Scale build-up in Tubing.
Lab Testing: Sub Surface Safety Valve (SSSV)

➢ **Objective:** Evaluate the effectiveness of WASP® to free a SSSV fouled with scale

➢ **Set-up:**
   - TRSSSV was hydraulically opened, cemented in place and allowed to cure
   - WASP® was run through the SSSV at 120 pulses per foot

➢ **Results:**
   - SSSV was fully operational
   - Cleaning the flapper itself requires placement of the WASP® across flapper and then releasing pressure allowing the flow tube to retract and exposing flapper
Case Study: Scale Removal at SCSSV on NUI

➢ Challenge:
  ➢ Operator had failed integrity test on Surface Controlled Subsurface Safety Valve (SCSSV)
  ➢ Well on this Normally Unmanned Installation (NUI) was producing oil at 3,500 bpd
  ➢ Operator believed failure due to Barium Sulphate scale build-up in tubing and at SCSSV
  ➢ Unable to use conventional methods due to scale restriction above SCSSV
  ➢ Operator required to shut-in well and set plug - as barrier - below SCSSV

➢ Solution:
  ➢ Blue Spark WASP® technology selected as preferred solution
  ➢ WASP® equipment & Engineers mobilised offshore & deployed with operator’s preferred wireline provider
  ➢ WASP® treatment performed across the SSSV – total well intervention time – less than 12 hours

➢ Outcome:
  ➢ SCSSV inflow tested – successfully
  ➢ Well back on production – increased to 5,000 bpd
Lab Testing: Side Pocket Mandrel (SPM)

- **Objective:** Evaluate the effectiveness of WASP® to remove scale from an SPM

- **Set-up:**
  - Entire pocket, including valve seat was filled with concrete and allowed to cure
  - WASP® was run along the length of the SPM at 120 pulses/foot

- **Results:**
  - Pocket and valve seat are completely free of concrete
  - No damage to SPM
Case Study: Scale Removal at Side Pocket Mandrel

➢ Challenge:
   ➢ A major North Sea operator encountered a leaking SPM with a Gas Lift Valve (GLV) insert, and required to replace it.
   ➢ The Kickover Tool (KOT) was unable to lock in the well-bore or latch onto the GLV, due to Barium Sulphate scale build-up on the SPM/GLV and in the tubing.
   ➢ Brushes, Downhole Jars & Exercise Tools were attempted without success.

➢ Solution:
   ➢ Blue Spark WASP® equipment & Engineer were mobilised offshore at short notice.
   ➢ WASP® toolstring deployed on operator's preferred wireline provider.
   ➢ WASP® treatment was performed across the SPM & also the tubing immediately above and below it.

➢ Outcome:
   ➢ Confirmation that scale was removed from SPM & tubing.
   ➢ LIB was run to verify condition of top of GLV.
   ➢ KOT was re-run and able to latch onto the GLV.
   ➢ Successful pressure test performed on SPM/GLV.
Surface Test – Slotted Liner
Surface Test – Slotted Liner

- A section of 5.5” slotted liner, plugged with scale, asphaltenes and fines was provided by a client.
- After 30 pulses, the slots and the inside of liner were clear of debris.
**SCALE REMOVAL**

Internal treatment of sand screen with 100% blocked flow paths internally and externally

<table>
<thead>
<tr>
<th>Before</th>
<th>After</th>
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</table>

**Sand Screen**
- OD 241.3mm (9 1/2”)

**Screen Apertures**
- Width 1.0 mm
- Phasing 360º

**Casing OD 220.9mm (8 5/8”)**
- Thickness 11.1mm

**Drilled Casing Hole Parameters:**
- Diameter 12.3 mm
- Phasing 27.7º
- Repeat 25.4mm
- Repeat Phase 13.8º

**Outer Cement Sheath**
- Thickness 38.2mm (1.5”)

**Inner Cement Sheath**
- Thickness 20.2 mm (0.8”)

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Case Study: Scale Removal at Sand Screen

➢ Challenge:
  ➢ A North Sea Operator suspected that a large section of sand screen across a productive zone was plugged by barium sulphate scale.
  ➢ However, the relatively low production rate, coupled with a small, unmanned production platform, precluded most other intervention solutions.

➢ Solution:
  ➢ An intervention was planned to clean a section of the slotted liner & sand screen.
  ➢ The Wireline Applied Stimulation Pulse (WASP®) tool was deployed using a wireline tractor. The client selected a section of liner to treat with the WASP®

➢ Outcome:
  ➢ Oil production increased to a 3 month average of 250.9 BOPD, nearly a 173% increase.
  ➢ Improved production was sustained for more than 6 months & the Operator chose to maintain the well as a producer, rather than convert it to an injector
Meshrite Cleaning
Before and After
New Applications and Processes

- New Wells
- Producing Wells
- Injection Wells
- Chemical Treatment
- Scale Removal
- Open Hole
Fluid Hold Up Tool

• Alternative for situations where there is no fluid at treatment interval

• Equipment that can hold enough fluid to cover the WASP®

• Highlights:
  ➢ Controllable fluid flow restriction
  ➢ Fluid injected from surface
  ➢ Limited to small sections (debris accumulation)
  ➢ Configure to maximize fluid retention while minimizing drag
FHUT Design – Configuration Options

• Various number and size of disks and washers are combined with spacers to customize the configuration for each wellbore

• The total length of the FHUT is only 0.6 m (24”); OD of main tool is 2-1/8”
North Sea Operator P&A testing

• Client Idea for new P&A concept
  • Intention is portion of surface casing where do not have enough height for 30m cement plug between permeable zones
  • Four Step Process
    • Drill holes in inner casing but not penetrate outer
    • WASP® Cement sheath to break up cement – Blue Spark
    • Circulate out Cement Debris
    • Melt a metal plug to make abandonment pressure seal

• Advantages
  • Completed before rig is mobilized
Testing results thus far
Timelines

- Concept Tests Aug – Oct 2017 YYC
- Concept Test Nov 2017 TLS
- Well Target Test – March 2018
- Tentative Real Well Test June 2018
WASP® + Acid Case Studies
CHALLENGE
The client operates 200 wells in a field, with only two water injection wells being used to maintain pressure in one portion of the field. Both wells suffer from near-wellbore damage due to scale and suspended solids. To treat the problem, acid stimulations were conducted every 6 to 8 months, but with diminishing rate of returns. The client was looking to reduce workover frequency and to increase injection rates.

HIGHLIGHTS
- Conventional oil field
- Vertically drilled
- Perforated
- Hydraulically fractured

LOCATION
NW Alberta

CONDITIONS
- Depth: 1800 m (5,900 ft)
- Temperature: 60 °C (140 °F)
- Montney Formation

OUTCOME
- The well saw an immediate increase in injection rates and a decrease in injection pressure.
- The average injection rate increased from a 3-month average of 97 bbl/d to 419 bbl/d for the first 3 months after WASP® + Acid.
- The increase was over 330%, compared to a 50% increase over 3 months for the last treatment done with acid alone.

RESULTS:
- Over 330% increase in water injection rate with WASP® + Acid vs 50% increase with acid alone

SOLUTION
- Improve connectivity to the reservoir by removing blockages using electro-hydraulic stimulation technology.
- The Blue Spark WASP® 212 (Wireline Applied Stimulation Pulsing) slim tool was run through tubing on third-party E-Line, avoiding the need to pull tubing.
- The perforated interval was 0.5 m in length and the stimulation was completed within an operating time of 3 hours.
- WASP® cleared the blockages in the formation to provide more surface area for a chemical treatment to be more effective.
- A mixture of solvent and acid was batched down the tubing of the well which was allowed to soak overnight.
- The well was put back on injection and monitored.

Water Injection Rates

- Most recent acid job
- Injection Well
- Chemical Treatment

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Challenges:
A 5-year-old disposal well was experiencing reduced injection rates and increased injection pressure. Over a 2-year period, 20 stimulations were conducted, averaging one treatment every 33 days. The client was looking for a cost-effective treatment that would:
- Improve injection rate
- Decrease injection pressure
- Reduce stimulation frequency

Location:
- NE Alberta
- Field: Kirby
- Depth: 500 m (1600 ft)

Solution:
- The Blue Spark WASP® ZT2 tool was deployed through tubing on third-party E-line and completed in 8 hours.
- Past WASP® customer chemical treatment conducted.
- 5X more effective than historical stimulation average.

Outcome
-Historical Treatment Comparison - Cumulative Injection Volume

<table>
<thead>
<tr>
<th>Stimulation</th>
<th>Longevity of Treatment (days)</th>
<th>30 Day Post Treatment Average</th>
<th>60 Day Post Treatment Average</th>
</tr>
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<tbody>
<tr>
<td>Acid - Feb 2013</td>
<td>27</td>
<td>466</td>
<td>2669</td>
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<tr>
<td>Acid - Sep 2015</td>
<td>34</td>
<td>114</td>
<td>3658</td>
</tr>
<tr>
<td>Frac - Oct 2015</td>
<td>101</td>
<td>449</td>
<td>3588</td>
</tr>
<tr>
<td>WASP + Acid - Nov 2015</td>
<td>170+</td>
<td>421</td>
<td>2988</td>
</tr>
</tbody>
</table>

Longevity of treatment determined by the operational well performance: injection pressure and injection rate.

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Questions?

Reconnect with your reservoir

New Wells  Producing Wells  Injection Wells  Chemical Treatment  Scale Removal  Open Hole

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